Research Paper | Biology | E-ISSN No : 2454-9916 | Volume : 10 | Issue : 10 | October 2024

LINKED EFFECTS: EXAMINING HOW MICROPLASTIC POLLUTION AFFECTS HUMAN HEALTH AND MARINE ECOSYSTEMS

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ABSTRACT

This research paper investigates the major ubiquitous problem of microplastic pollution and its influence on human health and marine ecosystems. Microplastics are minute particles measuring less than 5mm in size, resulting both from consumer products and environmental degradation, penetrating every part of our environment-from oceans and rivers to human bodies. Sources and distribution of microplastics: This paper takes a close look into the sources of microplastics and how they are distributed in daily products, from cosmetics to detergents to packages, everywhere in water and land ecosystems. Marine life: The vital focus here is on how microplastics affect marine life which ingestion causes digestive blockages, bioaccumulation of toxins, and disturbances of ecosystems.

The research further takes cognizance of the human health consequences, including ingestion and inhalation of microplastics through contaminated food, water, and air, thus leading to inflammation and oxidative stress, as well as chronic diseases. Finally, it emphasizes the interconnectedness of microplastic pollution by proposing a need for overarching mitigation strategies, policy reforms, and public awareness to meet this growing global concern. Secondary research and thorough literature reviews made for this paper have ensured an all-rounded understanding of just how microplastic pollution poses a critical threat not only to the environment but also to public health, thus requiring immediate attention.

KEYWORDS: Microplastic Pollution, Human Health Impact, Marine Ecosystems, Bioaccumulation, Environmental Contamination, Mitigation Strategies.

INTRODUCTION

Plastic permeates every corner of our world. Each year, a staggering 380 million tons of plastic are produced and consumed globally and some reports indicate that over 50% is single-use. However, the challenge lies in its disposal. Plastic is non-biodegradable and highly resistant to degradation, taking hundreds of thousands of years to break down. So, where does all this plastic end up once we're done with it? It finds its way into every imaginable place – our oceans, forests, and even forms vast garbage islands. Yet, amidst efforts to tackle the overarching issue, we must also confront a more immediate menace: microplastics. These minuscule plastic particles, measuring less than 5mm in diameter or length, pose a grave threat. Microplastics are generated through both deliberate and inadvertent means. They can originate from the gradual degradation of larger plastic debris, breaking down into tiny, microscopic particles over time. Additionally, microplastics are intentionally incorporated into various industries, notably cosmetics and healthcare. In products such as toothpaste, soaps, and facial scrubs, microplastic beads are commonly used which is a type of microplastic. While the full extent of their impact on human health remains an area of ongoing research, microplastics have been identified as a significant threat to marine life. Moreover, their ability to absorb and carry various toxins raises concerns about potential adverse effects on human health.

Background Study

Microplastics represent a burgeoning area of study with limited verified knowledge. These particles are typically classified as being smaller than 5mm in size. Composing various plastics like Polyethylene (PE), Polypropylene (PP), Polyethylene terephthalate (PET), Polystyrene (PS), and Polyvinyl chloride (PVC), with PE being the most prevalent, their chemical composition varies. One of the primary reasons for their existence is their persistence and resistance to degradation. It's important to recognize that the chemical makeup of microplastics can differ due to factors including their source, the type of consumer product they originate from, manufacturing methods, and environmental processes like weathering and degradation. At present, there are two distinct categories of microplastics: Primary and Secondary. Primary microplastics consist of particles or fragments intentionally produced for commercial purposes. These microplastics start at sizes less than 5mm without undergoing previous degradation or exposure to the environment; they are manufactured as microplastics from the outset. On the other hand, secondary microplastics are particles that have transitioned into microplastics as a result of the breakdown of larger plastic debris, like water bottles. This fragmentation of larger plastics into progressively smaller pieces is often influenced by factors such as UV radiation and the action of oceanic waves. An array of microplastic sub-types exists, including microplastic beads, fibres, foam, fragments, and nurdles. Despite microplastic's utilisation dating back

around 50 years, numerous background studies have been conducted, highlighting their pervasive threat to both marine and human life.

The objective of this paper

The objective of this study is to examine and evaluate the distinct effects of microplastics that come from environmental and consumer products on human health and marine ecosystems. The goal of the study is to present a thorough knowledge of the intricate relationship between microplastic pollution, human health, and marine ecosystems by looking at the interconnecting channels via which these effects occur. The study aims to determine the main mechanisms—such as exposure pathways, biological reactions, and ecological ramifications—by which microplastics impact human health and marine life by a detailed analysis of the body of research and empirical data. The paper additionally seeks to advance knowledge and comprehension of the detrimental impacts of microplastic pollution on human populations and marine habitats and find various mitigation solutions to address and prevent this upholding issue.

METHODOLOGY

The research endeavour will intricately weave together insights from the disciplines of environmental science, marine biology, toxicology, and public health, recognizing the interrelatedness that exists among these fields. Given the multifaceted nature of the inquiry, a diverse array of data collection methods will be deployed. However, the primary thrust of the methodologies will be rooted in secondary sources and research. At the core of the investigative process lies secondary qualitative research, which entails the reanalysis of existing qualitative data previously examined by other researchers for alternative research objectives. This reanalysis will be pivotal in elucidating the nuances of the research question within the broader context of microplastic impact assessment. By reexamining and reframing existing qualitative data through this lens, the research aims to unveil new perspectives and insights that contribute to a comprehensive understanding of the subject matter.

Complementing this approach, extensive literature reviews will be conducted to synthesise existing knowledge and identify gaps in understanding. These reviews will encompass a broad spectrum of scholarly works, including peer-reviewed articles, reports, and other relevant publications. Through meticulous examination and synthesis of this wealth of literature, the research endeavours to construct a cohesive narrative that illuminates the intricate dynamics surrounding microplastic impacts on diverse ecosystems and human health. Furthermore, the research will employ data analysis techniques to scrutinise and interpret quantitative data derived from existing sources. This analytical endeavour seeks to uncover patterns, trends, and correlations embedded within datasets, offering valuable insights into the complex interplay between microplastic pollution and environmental and public health outcomes. In tandem with these efforts, systematic reviews will be conducted to methodically assess and evaluate the quality and reliability of existing research studies. By systematically synthesising the findings of relevant studies, the research aims to distill robust evidence that informs the overarching objectives of the investigation.Additionally, the research will draw upon existing epidemiological studies to glean insights into the health impacts of microplastic exposure. Through careful examination and analysis of these studies, the research aims to discern patterns and associations between microplastic exposure and adverse health outcomes.

It is imperative to acknowledge that the research will be subject to certain limitations. Given resource constraints, the methodologies employed will be confined to secondary research approaches, precluding the possibility of primary data collection. However, by leveraging the breadth and depth of existing data and research, the research endeavours to advance understanding, raise awareness, and identify mitigation strategies pertaining to the impact of microplastics on environmental and public health.

Scope of the research

This research endeavours to address the inquiry: "What are the distinct impacts of microplastics from consumer products and the environment on human health and marine ecosystems, and how do interconnected pathways contribute to these effects?" In pursuit of this question, the study will explore various types of microplastics, their ramifications on marine life including symptoms and life-threatening consequences, diseases or illnesses inflicted upon marine animals, and their effects on bodily systems. Parallel analysis will be conducted for humans, elucidating similarities and discrepancies. The research will scrutinise the interrelatedness between these impacts on health systems, delving into intricate biological mechanisms connecting microplastics' detrimental effects on marine life and human health. Moreover, it will consider potential exacerbation of these issues in the future. The Research aims to display and be aware of data as well as talk about possible solutions that can be implemented. Delving into the depths of microplastics and how what it's made of affects what we are made of ?

In order to provide a complete understanding of the intricate relationships between microplastics, human health, and marine ecosystems, the research's scope includes a thorough evaluation of all currently available literature, including scientific studies, reports, and scholarly articles. The investigation will take into account the many routes of exposure, such as ingestion, inhalation, and skin contact, in addition to the potential pathways through which microplastics may impact ecological processes and biological systems. In general, the research attempts to advance knowledge of the effects of microplastic pollution on the environment and public health, as well as to provide guidance for the creation of efficient mitigation plans and awareness based on studies and research to deal with this expanding worldwide issue.

Understanding Microplastic Pollution: Sources, Distribution, and the Impact of Consumer Products on the Environment

Microplastics are minute plastics which are no more than 5mm in size. They are generated accidentally and deliberately, accidentally through the environment and deliberately in consumer products for us to use. Various cosmetic, skin

care and hygiene products have some concentration of microplastics. Some common daily use products which contain micro plastics are sunscreen, salt and pepper grinders, laundry detergents, toothpaste, nail polish, plastic films and many more have microplastics. Microplastics come from a variety of sources, such as the decomposition of bigger plastic objects over time as a result of environmental influences including UV rays and mechanical stresses. Additionally, microplastics enter ecosystems through runoff from industrial activities, abrasion of automobile tyres on roads, release of microbeads from personal care items, and shedding of synthetic fibres from fabrics during washing. The significance of comprehending the role that consumer products play in microplastic contamination is highlighted by their inclusion as a major source. Below is report containing reported concentrations of microplastics in air, dust, drinking water, sea food, food, beverages and human samples (taken from a website cited in citations)

Sample type	Location	Polymer type	Size	Concentration	Reference
Air					
Indoor	Aarhus, Denmark	Polyester, PE, nylon	0.004-0.398 mm	1.7-16.2 particles/m^3	(43)
	Edinburgh, UK	PET, PU	<5 mm	1666-1671 particles/m^2/d	(49)
	Paris, France	Not reported	0.005-0.6 mm	1586 – 11,130 particles/m^2/d	(50)
Outdoor	USA	Cotton, polyster, nylon, polyolefin, PTFE, PE	0.004 -3 mm	132 particles/m^2/d	(51)
	Asaluyeh county, Iran	Not reported	0.002-0.1 mm	72 items/m^3	(12)
	Hamburg, Germany	PET, ethylvinyl acetate copolymers	<0.063->0.3 mm	136.5 -512 particles/m^2/d	(52)
	Pyrenees mountains, France	PS, PE, PP, PVC, PET	<0.025-2.6 mm	366 particles/m^2/d	(53)
	Dongguan, China	PE, PP, PS, cellulose	<0.2-4.2 mm	175-313 particles/m^2/d	(54)
	Yantai, China	PS, PE, PP, PVC, PET	0.005-1 mm	0-602 particles/m^2/d	(55)
	Paris, France	Not reported	0.005-0.6 mm	2-355 particles/m^2/d	(56)
	Bushehr port, Iran	PET, PE, nylon, PS, PP	<2.5 µm	5.2 items/m^3	(57)
Dust particles					
Indoor	Several countries	PET	<2 mm	38–120,000 µg/g	(58)
	Shanghai, China	PS, polyamide, PP	50–2000 µm	4.4 ×10^3 MPs/m^2/d (mean)	(59)
	Surabaya, Indonesia		3000-3500 µm	212 particles (mean)	(60)
	Tiajin, China	PET	50 µm-2 mm	1550-120,000 mg/kg	(61)
		PC	50 µm-2 mm	4.6 mg/kg	
Outdoor	Tiajin, China	PET	50 µm-2 mm	212-9020 mg/kg	
		PC	50 µm-2 mm	2 mg/kg	
Drinking water					
Packed water bottle	Bangkok, Thailand	PET, PE, PP, polyamide, PVC	≥50µm	140 MPs/L	(62)
	Catania, Italy	PET	0.5 – 10 µm	657 ± 633 µg/L	(63)
Glass bottles	Erlangen, Germany	PE	>5 µm	6292 ± 10521 particles/L	(64)
Single use PET bottles				2649 ± 2857 particle/L	
Reusable PETbottles				195047 ± 330810 pigmented particle/L	
Reusable PET bottles				23594 ± 25518 pigmented particle/L	
Bottled water	NewYork, USA	PP, nylon	>100 µm	0-14 MPs/L	(65)
Packed mineral water	Germany	PET, PE, PP, polyamide	50-500µm	28 -241 MPs/L	(66)
Mineral water		PET		1 (only one found) MPs/L	(67)
Drinking water fountain	Metro-station, Mexico city	poly-trimethylene terephthalate	0.1-5 mm	5 ± 2 to 91 ± 14 MPs/L	(68)
Tap water	Qingdao, China	PE, PS, PET, rayon, polyester, polyacrylic, polymethylpentene, polyimide	10 to 5000 µm	0.3 - 1.6 MPs/L	(69)
	North-western Germany	PS, PVC, polyamide, epoxy resin, PE	>20 µm	0-0.0007 MPs/L	(70)
	Minneapolis, Minnesota, USA	Synthetic polymers	0.1-5 mm	5.45 particles/L	(71)
	Czech Republic	PET, PP, PE	<10 µm	469.6 MPs/L (mean)	(72)
	Different parts of China	PE, PP, PET	3 to 4453 µm	0 - 1247 MPs/L	(73)
Diet					
Sea salt	Bulgaria	PP	100-5000 µm	12 items/kg	(74)
Rock salt		PP, PE		8 items/kg	
Sea salt	China		45-4300 µm	550-680 items/kg	
Rock salt				43-364 items/kg	
Lake salt				7-204 items/kg	
Sea salt	France	PS	160-980 µm	0-2 items/kg	
Rock salt	Germany		100 µm	2 items/kg	
Rock salt	Hungary	Low density PE	100-4000 µm	12 items/kg	
Sea salt	India		1000-5000 µm	(30-370 items/kg	
Sea salt	Indonesia	PP		1400 items/kg	
Sea salt	Italy		1000-5000 µm	4-30 items/g	
Rock salt				80 items/kg	
Sea salt	Korea	PE	100-3000 µm	100-230 items/kg	
Rock salt	Philippines		100-5000 µm	120 items/kg	
Sea salt	Senegal		100-3000 µm	48 items/kg	
Rock salt				800 items/kg	
Sea salt	Thailand		100-5000 µm	70-400 items/kg	
Sea Salt	USA			50-800 items/kg	
Rock salt				113-367 items/kg	
Sea salt	UK		100-2000 µm	140 items/kg	
Sea salt	Vietnam		100-5000 µm	78-88 items/kg	
Beer	Germany		Not specified	2-79 fibers/L 12-109 fragments/L 2-66 granules/L	(75)
	Duluth, Minnesota, USA		100-5000 µm	0-14.3 particles/L	(71)
Honey	Germany, France, Italy, Spain and Mexico		10-20 µm	166 ± 147 fibers/kg 9 ± 9 fragments/kg	(76)
Sugar				217 ± 123 fibers/kg 32 ± 7 fragments/kg	
Honey	Switzerland		500 µm	1760 – 8680/kg (black particles) 132 – 728/kg (white fibers) 60-172/kg (white particles) 32-108/kg (coloured fibers)	(77)
Canned sardines and sprats	Australia and Malaysia		190-3800 µm	20 (mean) items/g	(78)
Seaweed nori	China		100-500 µm	0.9 - 3.0 items/g	(79)
Tea bags	Canada (billion microplastics and 3.1 billion nanoplastics single cup of the beverage)	fibers	25 µm	11.6 items/g	(80)
Oyster, bivalves and mussels (Seafood)					
Location	**Species name**	**Tissue**	**Size**	**Concentration**	**Reference**
California, USA	*Crassostrea gigas*	Soft tissue	>500 µm	0.6 particles/g	(81)
Brittany, France	*Crassostrea gigas*		5-25 µm	0.47 particles/g	(82)
Shanghai, China	*Meretrix lusoria*		5-5000 µm	9.22 paticles/individual	(83)
	Mytilus galloprovincialis		5-5000 µm	4.33 ± 2.62 particles/individual	
	Patinopecten yessoensis		5-5000 µm	57.2 ± 17.3 particles/individual	
Italy	*Mytilus galloprovincialis*	Hepatopancreas and gills	760-6000 µm	6.2-7.2 particles/g	(84)

Scottish coast	*Mytilus* spp. *Modiolus modiolus*	Soft tissue	200->2000 µm 200->2000 µm	3.2 ± 0.52 paticles/individual 3.5 ± 1.29 paticles/individual	(49)
Musa estuary, Persian Gulf	*Penaeus semisulcatus*	Muscle, skin	<100->1000 µm	7.8 particles/individual	(85)
Persian Gulf, Iran	*Pinctada radiata*	Soft tissue	10-5000 µm	11 particles/individual	(86)
East China Sea	*Mytilus* spp.		1000-5000 µm	3.69 ± 9.16 items/g	(87)
UK coast	*Mytilus edulis*		500 µm	0.7 to 2.9 items/g 1.1 to 6.4 items/individual	(88)
South Korea	*Crassostrea gigas, Mytilus edulis, Tapes philippinarum, Patinopecten yessoensis*		300 µm	Mean: 0.15 ± 0.20 n/g species and 0.97 ± 0.74 n/individual	(89)
Belgium coast	*Mytilus edulis*		200-1500 µm	2.6 to 5.1 fibers/10 g	(90)
Fuzhou, China	*Bivalve*		320-1600 µm	0.11-0.12 items/g and 0.59-1.44 items/individual	(91)
Xiamen, China	*Bivalve*		100-4000 µm	0.28-0.30 items/g and 1.26-1.56 items/individual	
Fishes					
Saudi Arabian Red sea coast	*Acanthurus gahhm* *Epinephelus areolatus* *Epinephelus chlorostigma*	Gastrointestinal tract	2700 µm 1800 µm 1900 µm	10 per g (mean) 10 per individual (mean) 3 per individual (mean)	(92)
Northeast Persian Gulf	*Alepes djedaba*	muscle	<100-5000 µm	20 per individual (mean)	(93)
Musa estuary, Persian Gulf	*Cynoglossus abbreviatus*	Muscle, gut, gills, liver, skin	<100->1000 µm	11 per individual (mean)	(85)
Mondego estuary, Portugal	*Dicentrarchus labrax* *Diplodus vulgaris*	Gastrointestinal tract	≤1000-5000 µm	40 per individual (mean) 40 per individual (mean)	(94)
Mediterranean Sea, Spain	*Engraulis encrasicolus*	Liver Gastrointestinal tract	124-438 µm Not specified	10 per individual (mean) 105 per individual (mean)	(95) (96)
Tokyo Bay, Japan	*Engraulis japonicus*		10-500 µm	64 per individual (mean)	(97)
Goiana estuary, Brazil	*Cynoscion acoupa*	Gut	5000 µm	552 per individual (mean)	(98)
Spanish Atlantic	*Merluccius merluccius*	Stomach	380-3100 µm	12 per individual	(99)
Indian coast	*Sardinella longiceps*	Gut	500-3000 µm	10 per individual	(100)
East China Sea	Wild fish species Crustacean spp.	Gill Gastrointestinal	24-268 µm 32-4092 µm	0.77 ± 1.25 items/individual 0.52 ± 0.90 items/individual	(101)
South China Sea	Deep sea fishes (13 species)	Stomach and intestine	40 – 200 µm	1.96 ± 1.12 items/individual and 1.77 ± 0.73 items/ individual	(102)
Fuzhou, China	Wild fishes	Gastrointestinal	440-11000 µm	0.60-0.85 items/g and 1.69-2.29 items/individual	(91)
Xiamen, China			450-7200 µm	0.49-1.28 items/g and 2.39-4.71 items/individual	(90)
Southern Caspian Sea	*Rutilus frisii kutum*	Stomach	<500 µm	11.4 itmes/fish	(103)
Northern Ionian Sea, Greece	*Mytilus galloprovincialis, Sardina pilchardus, Pagellus erythrinus, Mullus barbatus*	Gills, stomach, intestines	0.5-0.1 mm	1.7–2 items/individual and 1.5–1.9 items/individual	(104)
Bay of Bengal, India	*Marine fish (10 species)*	Gastrointestinal	<500 µm	2.2 ± 0.89 items/individual	(105)
Southern Caspian Sea	*Chelon Aurata, Rutilus kutum*	Gut	1.94 mm (mean)	2.29 MPs/fish	(106)
Human specimens					
Sample type	**Location**	**Polymer type**	**Size**	**Concentration**	**Reference**
Human placenta	Rome, Italy	PP and others	5-10 µm	12 fragments in 4 placentas	(46)
Human feces	Vienna, Austria	PP, PET	50 to 500 µm	20 MPs per 10 g of stool	(107)
Lung tissue	Sao Paulo, Brazil	PP, PE, PVC, cellulose acetate, polyamide, PS, PU	<5.5 µm particles and 8.1-16.8 µm fibers	Mean: 0.59 MP/g (470 particles per lung)	(108)
Pet feces	Albany, New York, USA	PET	<2.4 mm	Cat: <2,300-340,000 ng/g dw Dog: 7,700-190,000 ng/g dw	(48)
		PC	<2.4 mm	Cat: <32 to 13,000 ng/g dw Dog: <32-26,000 ng/g dw	

PE, polyethylene; PET, polyethylene terephthalate; PC, polycarbonate; PP, polypropylene; PU, polyurethane; PTFE, polytetrafluoroethylene; PS, polystyrene; PVC, polyvinylchloride.

To view the Table more clearly go to this website:
https://www.frontiersin.org/journals/endocrinology/articles/10.3389/fendo.2021.724989/full#B45

In Table 1, a compilation of products and substances containing microplastics is provided, detailing the type of microplastic present and its concentration level. It is noted that contaminated food and water are significant contributors to microplastic exposure.

As mentioned before secondary microplastics also have a high concentration such as dust and air as most humans get exposure via these sources. Primary microplastics are a result of breakdown of larger particles such as water bottles; these plastics usually breakdown due to exposure to sun radiation and ocean waves. Overall both primary and secondary sources are significant reasons for the source and existence of an estimated 75,000–300,00 tons of MPs are released by plastics breakdown annually in the EU and many more world wide.

Distribution and Abundance in Terrestrial and Aquatic Environments:

Microplastics are prolific and widely distributed in both aquatic and terrestrial environments. Various factors contribute to the dispersion of microplastics within these ecosystems. Processes such as wind, precipitation, river flow, and glacial ice transport microplastic particles to coastal regions. Additionally, microplastics are introduced to aquatic environments through wastewater discharge from industrial and domestic sources, ultimately finding their way into freshwater, marine, and saltwater ecosystems.

Numerous dispersion and influential factors contribute to the distribution and proliferation of microplastics within aquatic and terrestrial ecosystems. Among these factors are the intricate interplay of various mechanisms, including the intricate interplay of various mechanisms, including waterways, atmospheric deposition, sedimentation, natural processes, and human activity. These multifaceted drivers collectively shape the abundance and spatial distribution of microplastics, exerting profound impacts on environmental integrity and ecological balance.

Waterways, serving as conduits for the flow of materials, play a pivotal role in the dispersion of microplastics. They facilitate the transport of plastic particles originating from diverse sources, such as urban runoff, industrial discharges, and sewage effluents. Through the relentless movement of currents and tides, microplastics traverse vast distances across aquatic systems, perpetuating their widespread presence.

Atmospheric deposition emerges as another significant pathway through which microplastics infiltrate ecosystems. Minute plastic fragments, propelled into the air by human activities like industrial processes and vehicular emissions, settle onto land and water surfaces during precipitation events or as part of dry deposition. This aerial dissemination amplifies the spatial reach of microplastics, extending their influence beyond traditional aquatic realms to terrestrial environments.

Sedimentation processes intricately regulate the fate and dynamics of microplastics within aquatic habitats. As microplastics enter water bodies, they gradually settle and accumulate within sediment beds due to gravitational forces. However, these sediments are not static repositories; they undergo constant modification through natural phenomena such as wave action, riverine currents, and storm events, leading to the resuspension and redistribution of microplastic-laden sediments.

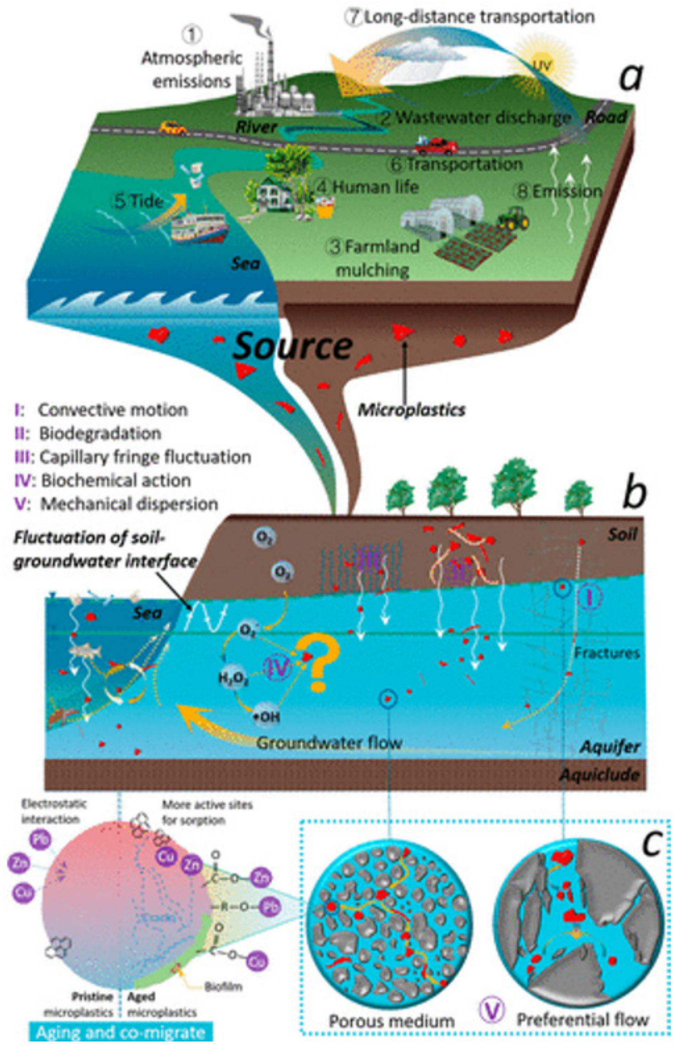
Natural processes, encompassing a myriad of geological, physical, and biological interactions, further shape the fate of microplastics in the environment. Physical weathering mechanisms, including abrasion and fragmentation, break down larger plastic items into smaller particles, augmenting their susceptibility to dispersion. Moreover, the activities of benthic organisms and aquatic fauna, through burrowing and ingestion, serve as conduits for microplastic mobilisation within ecosystems, integrating these pollutants into intricate food webs.

Human activity stands as a dominant force driving the proliferation of microplastics across ecosystems. The relentless production, consumption, and improper disposal of plastic materials perpetuate the influx of microplastics into the environment at every stage of the plastic lifecycle. From rampant plastic waste mismanagement to the pervasive littering of urban and coastal areas, anthropogenic activities exacerbate the pervasiveness of microplastic contamination. Additionally, industries such as shipping, fishing, and recreational pursuits contribute to microplastic inputs through direct emissions and secondary sources, amplifying the magnitude of this environmental challenge.

In concert, these dispersion and influential factors orchestrate the intricate tapestry of microplastic distribution and abundance, underscoring the urgent need for holistic strategies to mitigate this pervasive environmental menace. Efforts aimed at curtailing microplastic pollution must adopt a comprehensive approach that addresses the multifaceted pathways and drivers perpetuating its ubiquity across terrestrial and aquatic ecosystems.

Microplastics are widespread and abundant across various environments, with specific regions exhibiting higher concentrations. In aquatic environments, microplastics are prevalent in surface waters, encompassing rivers, lakes, and oceans, particularly in urbanised and coastal areas. Sedimentation plays a significant role in this distribution, as aquatic sediments act as reservoirs for microplastics, where particles settle and accumulate within riverbeds, lake bottoms, and marine sediments. Similarly, terrestrial environments also harbour accumulations of microplastics. Surface soils have been identified as locations where

microplastics are present, with landfills, dumping grounds, and illegal waste disposal sites emerging as focal points for microplastic contamination on land. These areas serve as hotspots for the deposition and accumulation of microplastics in terrestrial ecosystems but aquatic environments have majorly more MP's based on various studies. Below is a picture depicting the distribution and dispersion of microplastics

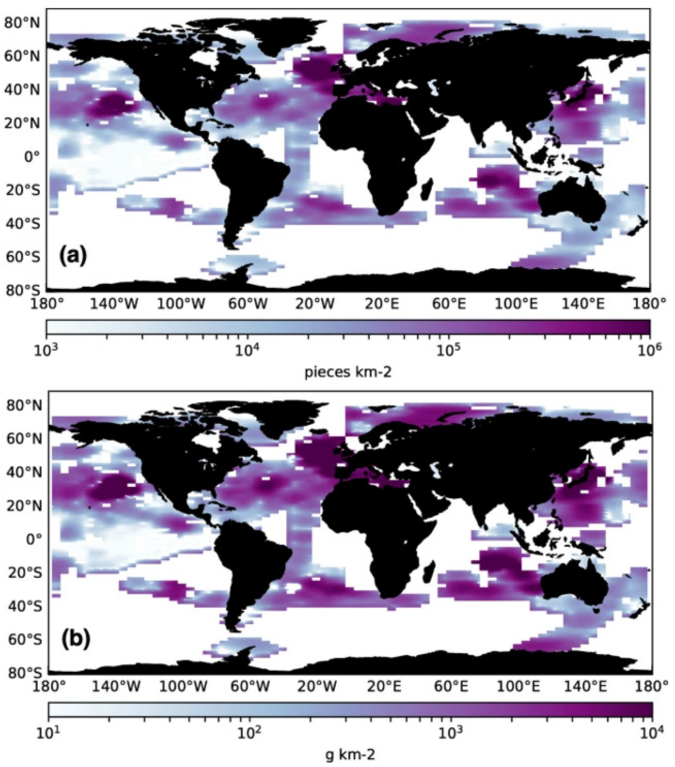


Microplastic particles are highly concentrated in numerous real-world locations across different regions worldwide. These areas include Africa, Asia, Southeast Asia, India, South Africa, North America, and Europe. Microplastics have been extensively distributed throughout the Earth's oceans. Notably,

microplastics are predominantly found in aquatic environments rather than terrestrial ones. In particular, during the cool dry season, water bodies exhibit a high abundance of microplastics, with concentrations ranging from 250 to 2600 particles per cubic metre, with an average of 1053 particles per cubic metre. One research study specifically examines the concentration of microplastics in the Baltic Sea. The Baltic Sea, boasting the largest coastal area globally, is a semi-enclosed reservoir of brackish water known for its susceptibility to contamination, particularly in terms of eutrophication and the presence of organic matter. Studies on marine litter and microplastics in the Baltic Sea indicate a significant presence of microplastics. Data reveals that the concentration of microplastics in Baltic Sea water ranges from 0.07 to 3300 particles per cubic metre, while in sediments, it ranges from 0 to 10179 particles per kilogram. These findings underscore the substantial contamination of microplastics in both the waters and sediments of the Baltic Sea.

The Ganga River, revered as one of India's holiest rivers, also contends with the unfortunate distinction of being among the world's most polluted waterways, with a notable presence of microplastics (MPs). The prevalence of textile industries and tanneries in Kanpur may contribute to the significant quantities of microplastics found in this section of the Ganga River. Elsewhere along the river, microplastic levels ranged from 1.56 to 2.11 MPs per cubic metre. In Varanasi, surface water samples from the Ganga River revealed a concentration of 2.42 MPs per cubic metre.

Below is an abundance map of where all microplastics are located and concentrated:



From this analysis, it becomes evident that South Asia, Southeast Asia, and China collectively account for approximately 68% of the world's mismanaged plastic waste. It is imperative to direct intensive studies towards locations where substantial amounts of mismanaged plastic waste are discharged. However, a notable limitation of the current dataset is the absence of microplastic data which was addressed in the research study for the Indian Ocean and the seas around Southeast Asia, including the South China Sea. In addition to waters adjacent to land masses, surveys conducted in the subtropical convergence zones, roughly spanning the 30° latitude in both hemispheres, should be prioritised to ascertain the overall extent of plastic pollution in the world's oceans. Overall from this it is noticeable how spread out and greatly abundant and distributed microplastics are.

Persistence and transport mechanisms:

Microplastics are like every other plastic, just smaller in size. Microplastics (MPs) are emerging as persistent pollutants, raising significant concerns for environmental health. Several factors contribute to their persistence. Firstly, microplastics exhibit chemical stability as they are composed of chemically stable polymers, rendering them resistant to degradation by biological and chemical processes. This inherent durability enables microplastics to endure in the environment for extended periods, spanning from decades to centuries. Additionally, their small size and shape play a pivotal role. Microplastics, defined as particles less than 5mm in size, persist across diverse environmental and climatic conditions. Smaller particles like microbeads and nanoplastics possess higher surface area-to-volume ratios, enhancing their stability and resilience to degradation. Various environmental factors, including temperature, UV radiation, pH, and salinity, influence the degradation rate of microplastics. While exposure to sunlight and oxygen can expedite degradation, microplastics buried in sediments or deep-sea environments may remain intact for prolonged durations. Transport mechanisms, such as sedimentation, water currents, atmospheric conditions, and biological processes, play crucial roles in distributing microplastics. Research indicates that river flow significantly influences microplastic transport compared to tidal cycles and wind. Wind, stormwater runoff, biofouling, aggregation, and salinity also impact microplastic distribution. Below is a table with methods for features of MP's from another study which can be used for the persistence aspect.

Table 1

Typical methods for the analysis of microplastics in the environment

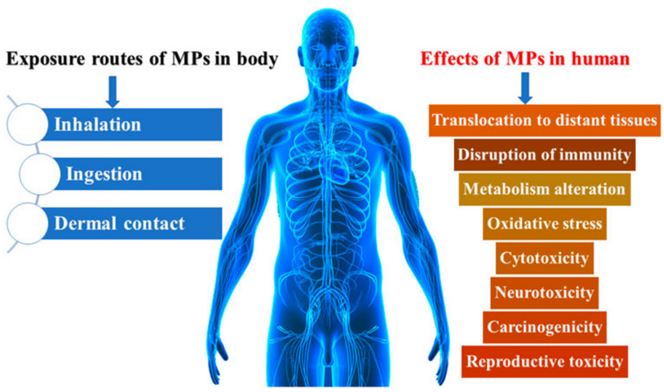
Methods	Advantages	Limitations
Visual analysis	A traditional method for the identification and quantification of microplastics (Hidalgo-Ruz et al. 2012). Visual analysis has the advantages of simplicity, low cost and low chemical hazard (von Moos et al. 2012)	Visual analysis method is time-consuming and laborious. Besides, when particle size of microplastics is too small or environmental samples contain impurities such as organic particles or inorganic particles, visual analysis method is no longer applicable (Hidalgo-Ruz et al. 2012; Shim et al. 2017; Song et al. 2015a). The accuracy and efficiency of visual analysis method is relatively low (Dekiff et al. 2014; Lavers et al. 2016). Visual analysis can't provide information about the chemical component of microplastics (Lavers et al. 2016). Visual analysis is usually only used as an auxiliary method for the analysis of microplastics
Scanning electron microscope-energy-dispersive X-ray	A promising technique that can be used to simultaneously analyze the surface morphology and elemental composition of microplastics (Eriksen et al., 2013; Fries et al. 2013; Van Cauwenberghe et al. 2013; Vianello et al. 2013)	The pretreatment process is complicated (Fu et al. 2020). The work efficiency is low and the cost is high. The estimation accuracy of the amount of microplastics is not very high. The color of microplastics can't be effectively distinguished (Wagner et al., 2017). This method is mostly used to detect specific microplastics
Fourier Transform infrared spectroscopy	A vibrational spectroscopy technology that can provide information on chemical bonds and functional groups in samples (Araujo et al. 2018; L¨der and Gerdts, 2014). This method has been widely used in qualitative detection and component analysis of microplastics	It can only be used for the identification of microplastics above 20 μm (Araujo et al. 2018; Prata et al. 2019; Schymanski et al. 2018). Besides, this method is easily affected by various factors
Raman spectroscopy	Another vibration spectroscopy technique based on inelastic scattering of light (Araujo et al. 2018). Besides, Raman spectroscopy can be used to identify the microplastics below 20 μm (Prata et al. 2019). Additionally, samples don't need to be dried and dehydrated before detection (Araujo et al. 2018). Raman spectroscopy and Fourier transform infrared spectroscopy can complement each other in the detection of microplastics (Käppler et al. 2016; Prata et al. 2019; Wright et al. 2019). This method has been widely used in the qualitative detection and composition analysis of microplastics	The detection time of Raman spectroscopy is relatively long (Araujo et al., 2018). In addition, Raman spectroscopy needs to be further improved in the analysis of microplastics (Löder and Gerdts, 2015; Prata et al. 2019; Sullivan et al. 2020)
Thermal analysis	A method of analyzing materials by studying their properties as a function of temperature and time (Majewsky et al. 2016). This method can be used to applied in the analysis of chemical characterization analysis and the mass concentration of microplastics	The sample pretreatment process is cumbersome. And this method is destructive to environmental samples, which means that this method can't be applied to the analysis of physical properties of microplastics (Huppertsberg and Knepper, 2018; Majewsky et al. 2016; Rocha-Santos and Duarte, 2015; Shim et al. 2017; Silva et al. 2018)
Mass spectrometry	An important method for the detection of polymers in microplastics (Weidner and Trimpin, 2010). Mass spectra of polymers can provide some important information on the structure, molecular weight, degree of polymerization, main functional groups and end group structure of polymers (Weidner and Trimpin, 2010). This method can be used for chemical characterization analysis and quantification of microplastics in environmental samples	The domain of application of this method is narrow (Huppertsberg and Knepper, 2018; Kirstein et al., 2016; Weidner and Trimpin, 2010). And this method is still so far incapable of quantifying total microplastics in the environment (Li et al. 2021b; Peng et al. 2020; Wang et al. 2017; Zhang et al. 2021)

The transport processes encompass a range of mechanisms, including surface drifting, vertical mixing, beaching, and settling. Overall, the persistence and transport mechanisms of microplastics are intricate processes contributing to their widespread distribution and environmental ramifications. Understanding these dynamics is imperative for evaluating the fate and behaviour of microplastics in the environment.

Impact on Human Health:

Microplastics pose a significant threat to human health, primarily through the ingestion of contaminated food and water and potential inhalation of particulates in polluted air. These particles, commonly found in seafood, salt, and drinking water, can infiltrate the body, initiating inflammatory responses that lead to inflammation of various organs and tissues.

Exposure pathways for microplastics entering the human body include consumption of contaminated food and water, inhalation of airborne particles, and dermal contact with contaminated surfaces. Upon ingestion, microplastics may traverse the gastrointestinal tract and accumulate in organs such as the liver, kidneys, and intestines. Inhalation of airborne microplastics can lead to their deposition in the respiratory system, potentially causing inflammation in the lungs and airways.

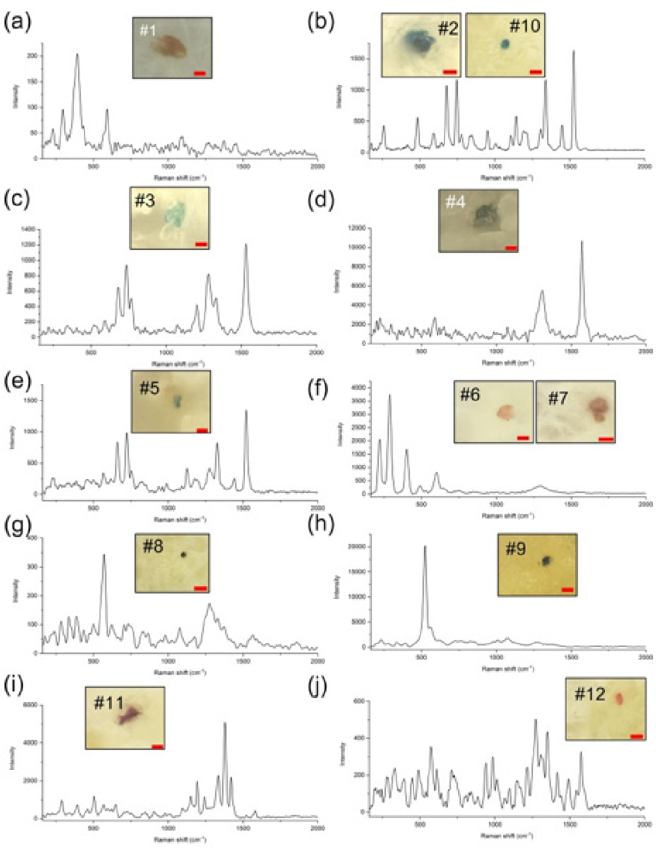


Additionally, dermal contact with microplastic-containing materials may result in localised inflammatory responses in the skin. Microplastics have been associated with adverse health effects, including oxidative stress, immune system dysregulation, and tissue damage.In a recent study, findings indicated that nano-sized plastics were linked to mitochondrial impairment in human respiratory cells. Inflammatory reactions triggered by microplastic exposure can exacerbate pre-existing conditions and contribute to the development of diseases such as asthma, cardiovascular disorders, and gastrointestinal disorders. Moreover, the accumulation of microplastics in vital organs and tissues may disrupt cellular functions and metabolic processes.

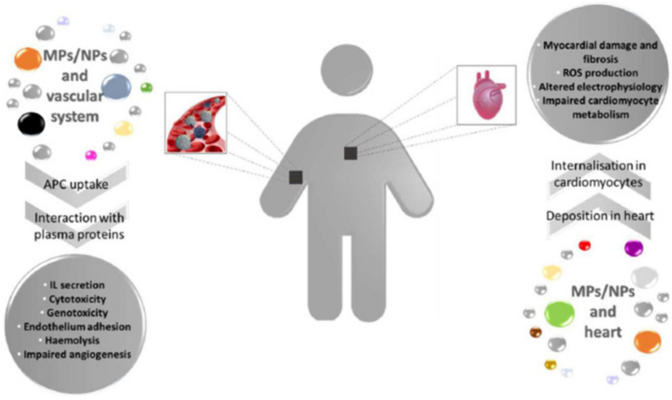
Various chemicals have the potential to leach from common items like plastic water bottles, cutlery, and dermatologic products, entering our bodies. These compounds have been associated with serious health concerns, including endocrine disruption, weight gain, insulin resistance, decreased reproductive health, and cancer. Animal experiments have demonstrated that prolonged exposure to microplastics can induce chronic inflammation and disrupt homeostasis. Moreover, research on

human lung cells has shown that microplastics can activate innate immunity by modulating the expression of genes and proteins involved in the immune response. Concerns also extend to reproductive toxicity, as certain microplastics have been found to interfere with hormone levels and reproductive processes, potentially affecting development and fertility. Compounds like phthalates and bisphenol A, present in some microplastics, have been linked to health issues such as cancer and hormone disruption, contributing to various endocrine disorders, including metabolic and developmental disorders. Therefore, there is a pressing need to minimise exposure to these widespread pollutants. Additionally, microplastics can serve as carriers of environmental toxins, such as polystyrene (PS), which, when present in high concentrations, pose risks to human lung cells and may increase the likelihood of chronic obstructive pulmonary disease.

A recent study discovered concentrations of microplastics in 6 placenta which can possibly open up the area that MP's can seriously harm humans, below is the image of the graph with its placenta.



From all these samples, 6 turn out to have some kind of microplastic in them, but this has not been the only study. In another study, researchers discovered polyethylene in the hearts of over 58% of the 257 patients who were studied and subsequently followed up with. Additionally, more than 12% of these patients had PVC particles present in their arterial plaques. Those individuals who exhibited microplastics in their plaques also displayed indications of inflammation in their bodies and were significantly more prone to experiencing heart attacks, strokes, and mortality from any cause compared to patients who did not show evidence of microplastics migrating to their hearts.



Microplastics (MPs) and nanoparticles (NPs) can impact the vascular system and heart in mammals. They enter the human body through various pathways and are absorbed into vascular system cells, prompting various cellular reactions. Furthermore, MPs/NPs can infiltrate cardiac tissue, leading to both structural and metabolic harm.

Due to the potential for microplastics to enter the body through ingestion, inhalation, and skin absorption, there is growing concern about their accumulation in the human body. Once ingested, microplastics can accumulate in various tissues and organs, posing potential risks to health. Additionally, microplastics have the ability to biomagnify in the food chain, leading to higher concentrations in organisms higher up the food chain, thereby increasing the likelihood of human exposure through consumption of seafood and animal products. While research on the full spectrum of health effects related to microplastic accumulation and biomagnification is ongoing, it is evident that urgent action is needed to address plastic pollution and protect human health.

Several key research studies contribute to our understanding of the impact of microplastics on human health. For instance, a 2019 study titled "Globally Sourced Microplastics in Human Stool," published in Environmental Science & Technology, revealed the presence of microplastics in every stool sample examined, underscoring the widespread nature of microplastic exposure. Similarly, studies on the "Immunotoxicity of Microplastics in Mice," published in Environmental Science & Technology Letters in 2019, shed light on potential inflammatory effects in humans. Additionally, research on "Occupational Exposure Among Plastic Industry Workers" provides valuable insights into health concerns associated with high levels of microplastic exposure. Together, these research efforts underscore the importance of ongoing investigation and preventive measures to reduce human exposure to microplastics and mitigate the broader issue of plastic pollution.

Impact on Marine Ecosystems

Microplastic pollution exerts detrimental effects on marine life and ecosystems. While microplastics are present in both terrestrial and aquatic environments, the majority is found in

oceans, rivers, lakes, and various water bodies due to factors such as biota, sedimentation, and wastewater runoff. Biota play a significant role in the exposure of aquatic ecosystems to microplastics, as many marine organisms, ranging from small zooplankton to larger fish and marine mammals, ingest them either deliberately or inadvertently during feeding. Microplastics often resemble plankton or other prey items, making them attractive to filter-feeders like bivalves, copepods, and certain fish species. Additionally, organisms higher in the food chain may consume prey already containing microplastics, leading to indirect ingestion.

Microplastics have the capacity to adsorb and accumulate persistent organic pollutants (POPs) and other hydrophobic contaminants from the surrounding water. When organisms ingest microplastics, they may also ingest these associated pollutants, potentially leading to bioaccumulation within their tissues over time. This bioaccumulation can reach levels of concern for both individual health and ecosystem functioning. Moreover, ingested microplastics can cause physical harm to organisms by causing blockages or damage to the digestive tract, impairing feeding and digestion. Additionally, microplastics can act as carriers for pathogens, algae, and other harmful microorganisms. When ingested, these microorganisms may be released within the organism's digestive system, potentially causing infections or other adverse effects. Below is an image of how a fish's cardiovascular system is affected by MP'S.

Species	Microplastics				Organ affected	Toxic effect	References
	Type	Size	Colour	Concentration			
Scophthalmus maximus	Ethylene propylene	50–200 μm	Black and blue	-	Liver and gills	Gills contain more concentration of microplastics	Köktürk, et al. (2023)
						Oxidative damage mostly affected the liver and gills	
Oreochromis mossambicus	Polypropylene	-	-	100, 500, and 1,000 mg/kg	Liver	Fluctuations in homeostasis and increased ROS levels	Jeyavani et al. (2023)
						Higher apoptosis, DNA damage (genotoxicity), and histological changes	
Danio rerio	Propylene copolymer	-	-	0.1—1 mg/L	Brain, liver	Anxiety, ROS generation, mitochondrial dysfunction	Félix et al. (2023)
Nothobranchius guentheri	Polystyrene	5 μm and 15 μm	Blue	10 mg/L	Liver	Induced oxidative stress, reduced antioxidant and digestive enzymes, and hepatic dysfunction	Xia et al. (2020)
Ctenopharyngodon idella	Polystyrene	0.5 μm, 15 μm	-	100 μg/L, 500 μg/L	Liver	Induced oxidative stress and liver congestion	Hao et al. (2023)
						Altered gut microbiota and severe intestinal damage	
Oryzias latipes	Microfiber types microplastics	-	-	100 and 1,000 fibers/L	Liver	Increase in CAT, SOD, MDA and caspase-3	Kim et al. (2023)
						Induced apoptosis and DNA damage	
Pseudobagrus fulvidraco	Polyethylene	-	-	100, 200, 5,000 and 10,000 mg/L	Gut, gills and liver	Decreased RBC, Hb, haematocrit (Ht), calcium total protein and magnesium	Lee and Kim. (2023)
						Increased SOD, CAT and GST, decreased GSH	
Sparus aurata	Polystyrene	1–20 μm	-	25 and 250 mg/kg	Intestine	Increased ROS and MDA.	Del Piano et al. (2023)
						Altered SOD, CAT and GSH.	
						Upregulation of HSP70 and HSP90	

Oreochromis niloticus	Polyacrylamide	0.1–0.4 mm	-	0.018, 0.03 0.09 g/L	Gills, liver and intestine	Reduced CAT and GSH. Increased MDA and lipid peroxidase levels	Raza et al. (2023)
Danio rerio and *Perca fluviatilis*	Polyethylene	10–45 μm and 106–125 μm	-	-	Liver and gills	Induced oxidative stress, DNA damage, lipid peroxidation and ubiquitination	Bobori et al. (2022a)
Danio rerio and *Perca fluviatilis*	Polypropylene	8–10 μm	-	1 mg/g and 10 mg/g	Liver and gills	Induced oxidative stress, DNA damage and apoptosis	Bobori et al. (2022b)
Xiphophorus helleri	Polystyrene	1 μm	-	-	Liver	Decreased antioxidant function, immunity, energy metabolism and growth performance Weakened feed utilization	Zhang et al. (2022a)
Squalius squalus, *Blicca bjoerkna*, Capoeta umbla *Capoeta trutta*, *Cyprinus carpio* *Mugil cephalus* *Atherina mocho*	47 microplastics	0–50, 50–100 μm	Black	-	Gastrointestinal tissues	Decreased SOD and CAT Increased ROS and MDA	Atamanalp et al. (2022)
Sparus aurata	LDPE	100 and 500 μm	-	-	Liver	Increased SOD, GRd, GST, MDA and caused oxidative damage	Capó et al. (2021)
Gambusia affinis	Polyethylene, polystyrene, polyvinylchloride, polyamide, and polycarbonate	-	-	-	Digestive tract and gills	Increased CAT, SOD and MDA	Buwano et al. (2022)
Oreochromis niloticus	Microplastics	>100 nm	White	1 mg/L, 10 mg/L and 100 mg/L	Liver	Decreased antioxidant capacity and increased ROS production	Hamed et al., 2020
Oryzias melastigma	Polystyrene	10 μm		2, 20, and 200 mg/L	Gill, intestine, liver, testis and ovaries	Increased CAT, GSH-PX and decreased GSH. Changes in sex hormone levels	Wang et al. (2019)
Cyprinus carpio	PVC	-	White	45.55 μg/L, 91.1 μg/L, and 136.65 μg/L	Liver, intestine and gills	Induced oxidative stress Decreased MDA and antioxidant activity	Xia et al. (2020)
Carassius auratus	Polyvinyl chloride	-	-	0.1 or 0.5 mg/L	Liver, intestine and gills	Increased GST, MDA, H_2O_2 activity and CYP1A expressions Induced inflammation, hemorrhaging and necrosis	Romano et al. (2020)
Oryzias javanicus	Polystyrene	5 μm	White	100, 500 and 1,000 μg/L	Gut, liver, kidney and brain	Induced oxidative stress, lipid peroxidation neurotoxicity and inhibited AChE	Usman et al. (2021)

Disruption of Ecological processes:

Due to the presence of microplastics The ecological ramifications of microplastics in aquatic ecosystems are extensive and complex, impacting various trophic levels and disrupting crucial ecological processes. At the foundational level of the food chain, microplastics tend to amass in aquatic sediments, altering their composition and affecting nutrient cycling (Shukur et al., 2023). This disturbance can induce shifts in primary production, potentially influencing the entire ecosystem.

Wastewater acts as a conduit for transporting pathogens, nutrients, contaminants, and solids into the ocean, which can result in coral bleaching, disease, and mortality among coral, fish, and shellfish. Microplastic pollution can contribute to a decline in marine biodiversity by directly harming individual organisms and indirectly affecting their habitats and food sources. The reduction in biodiversity can diminish ecosystem resilience and stability, rendering marine ecosystems more susceptible to environmental stressors. Microplastic pollution disrupts the provision of ecosystem services in marine environments, such as nutrient cycling, carbon sequestration, coastal protection, and fisheries production. This disruption can have profound repercussions for human well-being and socioeconomic systems reliant on marine resources. Microplastics can adsorb and transport pollutants and nutrients,

thereby influencing nutrient cycling in marine ecosystems, altering nutrient availability, fluxes, and primary productivity.

Microplastic pollution can interfere with species interactions and trophic relationships within marine food webs. For instance, microplastics ingested by zooplankton may accumulate in their tissues, affecting predator-prey dynamics and energy transfer throughout the food chain. Microplastics can accumulate in marine sediments, modifying benthic habitats and impacting the distribution and abundance of benthic organisms. This alteration of habitats can lead to shifts in community structure, species composition, and ecosystem functioning. When animals ingest microplastics, they also ingest associated toxic chemicals. These substances accumulate in their bodies, gradually propagating up the food chain, resulting in decreased growth and reproduction. Microplastics also harbour a plethora of toxins beyond their inherent chemicals, thus serving as carriers for additional hazardous bacteria and chemicals

Case studies of microplastic impacts on marine species and ecosystems

Microplastics are ingested by various marine animals, including seabirds, crustaceans, and fish. In the north Pacific central gyre, microplastics were found in the intestines of 35% of planktivorous mesopelagic fish. Additionally, plastic fibres, fragments, and coatings were detected in 13 out of 141 mesopelagic fish captured in the same region. Moreover, a study conducted in the Clyde Sea (Scotland) revealed that 83% of Nephrops sp. had consumed pollutants. This benthic crustacean, which is economically valuable and omnivorous, predominantly ingested portions of monofilament line and plastic bag shards.

Recently, Sun et al. conducted research on the cardiovascular toxicity of nanoparticles (NPs) in zebrafish embryos. The findings showed that NPs could hinder sub-intestinal angiogenesis, potentially leading to impaired cardiovascular formation and development. Additionally, a hypercoagulable state was observed in the caudal vein, characterised by erythrocyte aggregation, neutrophil recruitment, and an increased incidence of thrombosis following NPs exposure. Hemodynamically, decreased carbon monoxide levels and blood flow rates were evident in the treated groups, particularly at concentrations of 100 and 200 µg/mL, suggesting dose-dependent effects. These hemodynamic changes can exacerbate the thrombotic process by increasing vascular resistance, leading to elevated blood pressure and myocardial contraction. Furthermore, the study found increased reactive oxygen species (ROS) production and a generalised inflammatory response at concentrations of 100 and 200 µg/mL, indicating broader physiological impacts of NPs exposure. In another study by Barboza et al. (2020), microplastic contamination in Atlantic horse mackerel (Trachurus trachurus) and Atlantic chub mackerel (Scomber colias) was investigated. The research revealed that microplastics were present in the dorsal muscle, gastrointestinal tract, and gills of 49% of the analysed fish. Moreover, microplastic-contaminated fish exhibited increased levels of lipid peroxidation (LPO) in the brain, dorsal muscle, and gills, along with higher brain acetylcholinesterase (AChE) activity compared to control groups.

Below are two tables talking about how certain fish's cardiovascular system is affected by various studies.

Table 1

Summary of the main features of MPs/NPs in studies on the cardiovascular (CV) system of aquatic organisms included in the present review. PS: polystyrene; PE: polyethylene; AChE: acetylcholinesterase; GGT: gamma glutamyl-transferase; AST: aspartate aminotransferase; ALT: alanine aminotransferase; ALP: alkaline phosphatase; LDH: lactate dehydrogenase; ACH50: alternative complement activity.

Organism	Type of Particles	Size of Particles	Observed Effects on CV System	Reference
Zebrafish (*Danio rerio*)	PS	5 µm and 70 nm	Bioaccumulation in gills (transfer to capillaries)	[44]
Red tilapia (*Oreochromis niloticus*)	PS	0.1 µm	Bioaccumulation in gills and transfer to capillaries	[45]
Blue mussel (*Mytilus edulis*)	PS	3.0 or 9.6 µm	Transfer to capillaries, internalisation into haemocytes	[46]
Common carp (*Cyprinus carpio*)	Mixture (mainly PE)	Mixed	Reduced plasma levels of AChE and GGT, and increased AST, ALT, ALP and LDH, lowered lysozyme and ACH50 activities, lowered total immunoglobulins and complement C3 and C4 factors	[48]
Marine medaka (Oryzias melastigma)	PS	10 µm	Bioaccumulation in gills, ROS production and histopathological changes in loco	[49]
Zebrafish (*Danio rerio*)	PE	Mixed (191.10 ± 3.13 nm)	Vascular endothelium damage and compromised angiogenesis, pro-thrombotic state. Altered hemodynamic	[50]
Mediterranean mussel (Mytilus galloprovincialis)	PS	50 nm	Blood cells apoptosis, compromised immunocompetence	[51]

Table 2

Main characteristics of MPs/NPs and effects on cardiac tissue of aquatic fauna. PE: polyethylene; PS: polystyrene.

Organism	Type of Particles	Size of Particles	Observed Effects on Heart	Reference
Zebrafish (*Danio rerio*)	PE	Mixed (191.10 ± 3.13 nm)	Pericardial oedema	[50]
Zebrafish (*Danio rerio*)	PS	42 nm	Bradycardia	[53]
Zebrafish (*Danio rerio*)	PS	51 nm	Bioaccumulation in pericardium, bradycardia	[54]
Marine medaka (Oryzias melastigma)	PS	10 µm	Bradycardia	[49]
Goldfish (*Carassius auratus*)	PS	70 nm and 5 µm	Tachycardia	[55]

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Results from fecal samples suggest that residents of Hong Kong may have significantly higher ingestion rates of microplastics compared to individuals in other regions of Asia and Europe, potentially up to five times higher.

Recent research has brought to light the capacity of filter-feeding copepods, bivalve, and decapod larvae to ingest microplastics. Notably, microplastics were found to be significantly diminished by the algal feeding of copepods such as Centropages typicus and Calanus helgolandicus. Prolonged exposure to microplastics was observed to result in reduced egg size and hatching success, as well as diminished survival rates among C. helgolandicus due to declining energetic reserves.

Globally, fish play a crucial role in providing animal protein to approximately 4.3 billion people, constituting around 15% of their dietary protein requirement. While many fish species readily ingest microplastics, the health effects on these organisms remain uncertain. Studies suggest that fish exposed to microplastics may incorporate them through their gills and digestive tract. For instance, Grigorakis et al. (2017) suggested that microplastics ranging from 50 to 500 µm in goldfish (Carassius auratus) may accumulate only in the gastrointestinal tract rather than in the skin and tissues. Additionally, Avio et al. (2015) reported the translocation of smaller microplastic

particles (<600 µm) from the digestive tract to the liver tissues of Flathead grey mullet (Mugil cephalus).

De Vriese et al. (2015) studied microplastic particles in shrimp and found plastic fibers at a rate of approximately 9 fibers per 10 g of shrimp. Moreover, crustaceans exposed to polystyrene microbeads have shown reduced fecundity, developmental delays in offspring, decreased food uptake, impairment of enzyme activity, and alterations in behavior. The impact of polystyrene (PS) microspheres on the Pacific oyster was documented by Sussarellu et al. (2016), who observed effects on reproductive cycles when adult oysters were exposed to 2 and 6 µm size polystyrene. Further, Naji et al. (2019) found higher concentrations of microplastics in mollusks, suggesting trophic transfer of microplastics in the food web. Studies on scleractinian coral species conducted by Chapron et al. (2018) revealed that corals predominantly egest most of the microplastics they ingest, although both micro and macro plastics significantly reduced skeletal growth rates in Lophelia pertusa.

Overall, while the full extent of microplastic pollution's impact on aquatic environments is yet to be fully elucidated, previous studies indicate global concerns regarding its adverse effects on marine life.

Interconnected Pathways

The review explored the hypothesis that chemical additives on microplastics (MPs) accumulate and magnify across marine food webs. It synthesised data from 116 papers on marine life pollution with MPs, showing accumulation across trophic levels and higher absorption of additives when exposed alone versus with MPs. While laboratory studies demonstrated trophic transfer, field data did not support biomagnification. Bioaccumulation is crucial for water quality assessment, with EQSbiota being more relevant than EQSwater for bioaccumulative compounds. Biota monitoring, along with event-related monitoring, helps identify contamination sources. Improved evaluation of bioaccumulation potential is needed for new monitoring programs, with standardised methods and interlaboratory exercises recommended.

The marine ecosystem contains microplastics, contaminating seafood and potentially affecting humans. Over 90% of ingested micro- and nanoplastics are eliminated by the human body, but retention and clearance vary due to factors like size, shape, and chemical composition. Research suggests potential consequences such as gut flora disturbance, pollutant transfer, and inflammation, despite incomplete understanding of physical effects. Microplastics can traverse mammalian cells, accumulating in secondary organs and impacting immune function. Laboratory experiments indicate negative effects on marine species, including immunological responses and organ stress. Below is a study of seafood

Table 3

Major Seafood Items with High Consumption of Microplastics

Food group	Selection criteria	Target marine products
Fish (20 species)	Intestines consumed (muscles or intestines)	Yellow corvina, stingray, pike eel (liver), halibut, perch, cod, flounder, croaker, rockfish, conger eel, monkfish, and skate
	Whole fish consumed (whole fish, muscles, or intestines)	Snakehead, crucian carp, and carp
	Specific organs consumed (muscles, intestines, or specific organs)	Sandfish (roe), pollack (roe), frozen pollack (roe), and conger eel (liver)
Shellfish (8 species)	Conches (muscles or intestines, including reproductive organs)	Conch, triton snail, abalone, big snail, and rice paddy snail
	Larger shellfish among invasive shellfish (muscles or intestines, including reproductive organs)	Scallops, cockles, and razor shell
Crustaceans (6 species)	Marine decapods (muscles or intestines)	Blue crab, snow crab, red crab, stone crab, king crab, and lobster
Mollusks (4 species)	Cephalopods (muscles or visceral mass, including reproductive organs and ink)	Cuttlefish, squid, small octopus, and octopus
Echinoderms (1 species)	Specific organs consumed (edible parts or intestines)	Sea cucumber
Deep-sea fish (2 species)	Large marine animals or fish (muscles, intestines, tails, fins, or eggs)	Whale, shark (eggs)

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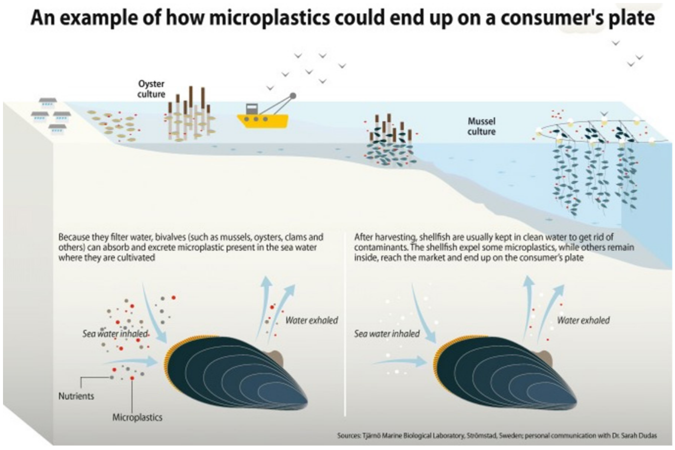
High microplastic pollution levels are found in various marine species, especially in coastal Asian regions, with significant differences in species microplastic content. Estimated human intake can reach up to 55,000 particles annually, emphasising the need for further research to assess seafood-related microplastic exposure risks and develop effective risk management strategies.

Microplastics are prevalent in various species intended for human consumption, including invertebrates, crustaceans, and fish. These particles are often concentrated in the digestive tracts of organisms, with bivalves and small whole fish being more likely to expose microplastics to the human diet. Research by Van Cauwenberghe and Janssen revealed that farmed mussels had significantly higher microplastic concentrations compared to wild-caught mussels. Additionally, studies by Rochman et al. identified the presence of microplastics in commercially sold, wild-caught fish from markets in Indonesia and California.



These findings indicate that the challenge of microplastic contamination in seafood could be widespread due to its ubiquity in the environment and the potential translocation of particles to animal parts commonly eaten by humans. However, there is currently limited information regarding the direct transfer of additives from plastic to human tissues, highlighting

the need for further research in this area. The absorption of microplastics leads to bioaccumulation and biomagnification across the food chain, posing potential risks to human health through dietary exposure.

Studies have also detected microplastics in various food items such as fish, shellfish, table salt, and drinking water. Furthermore, microplastics have been found in human feces collected from different populations worldwide, suggesting human ingestion and their presence in the gastrointestinal tract. However, detailed information on human exposure to microplastics remains insufficient, highlighting the need for continued research in this field. The table below shows the findings

Table 1

Selected studies of microplastics in faeces of healthy human cohorts in Asia and Europe.

Sampling Region	China (Hong Kong)	China (Beijing)	Indonesia (a Rural Village of Pacet)	Japan (Tokyo) and Europe (7 Cities [1])
Sample size and gender	4 men and 4 women	24 men	5 men and 6 women	3 men and 5 women
Years of age	30–65	18–25	20–50	33–65
Prevalence of MP [2]	100%	96%	64%	100%
Quantity of MP, range	20.4–138.9 particles g^{-1}	1.0–36.0 particles g^{-1}	6.9–16.5 μg g^{-1}	0.8–41.6 particles g^{-1}
Quantity of MP, mean ± SD	50.3 ± 39.0 particles g^{-1}	8.9 ± 8.5 particles g^{-1}	12.2 ± 4.1 μg g^{-1}	9.3 ± 14.8 particles g^{-1}
Quantity of MP, median	36.4 particles g^{-1}	6.5 particles g^{-1}	12.4 μg g^{-1}	2.0 particles g^{-1}
Detected size range of MP	30–1800 μm	20–800 μm	Not reported	50–500 μm
Major polymers of MP	PS > PP > PE > PET [2]	PP > PET > PS > PE	PP > PE > PS > PET	PP > PET > PS > PE
Major shapes of MP	Fragment > fibre	Not reported	Not reported	Fragment and film > sphere and fibre
Spectroscopic approach	Raman	FTIR [2]	Raman	FTIR
Reference	Present study	[10]	[7]	[6]

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[1] United Kingdom (Birmingham), The Netherlands (Groningen), Italy (Sassari), Austria (Vienna), Poland (Toruń), Finland (Enontekiö) and Russia (Krasnoyarsk); [2] Abbreviations: microplastics (MP), polystyrene (PS), polypropylene (PP), polyethylene (PE), polyethylene terephthalate (PET) and Fourier-transform infrared (FTIR).

Results from faecal samples suggest that residents of Hong Kong may have significantly higher ingestion rates of microplastics compared to individuals in other regions of Asia and Europe, potentially up to five times higher.

In conclusion, we can observe the feedback loops between marine life and humans. These loops can lead to a continuous cycle of microplastic contamination and its potential impacts on human health, with each affecting the other in complex ways. The intricate interplay between environmental pollution and human health, particularly concerning microplastics, underscores the urgent need for comprehensive action and interdisciplinary collaboration. Furthermore, research efforts must continue to expand our understanding of the pathways and impacts of microplastics on both environmental and human health. This includes investigating the bioaccumulation and biomagnification of microplastics in marine food webs, elucidating the mechanisms of human exposure and potential health effects, and developing effective monitoring and risk assessment strategies. Currently, no one is able to fully determine how microplastics from seafood could have a severe effect on human health, but many studies are being carried out, which means there is a significant reason to research because, as of now, our digestive system digests 90% of the microplastics entering our body without letting them harm any of our organs.

CONCLUSION:

Through qualitative research, it has become evident that microplastics represent an imminent threat to both environmental and public health. It is imperative for us to raise awareness about this issue, recognizing the interconnected nature of our actions and their repercussions. Microplastics, originating from our daily consumption and activities, ultimately return to haunt us through various interconnected loops. This underscores the urgency for legislative policies and mitigation measures to be implemented.

The severity of the issue necessitates a comprehensive understanding of the consequences and effects of microplastics on both human health and marine life. Widespread contamination has been observed across various ecosystems, including freshwater bodies, oceans, and even the air, highlighting the pervasive nature of the problem. Studies have demonstrated the dangers posed by microplastics to human health, showing their presence within the body and their potential to cause harm. This underscores the urgent need for action to address microplastic pollution and mitigate its impacts on both environmental and public health.

In conclusion, microplastic pollution poses a significant threat that requires immediate attention and action. By raising awareness, implementing legislative policies, and adopting mitigation measures, we can work towards mitigating the adverse effects of microplastics and protecting the health of our planet and future generations.

Below is a study about severe illness caused by MP concentration in the human body:

Toxic effects	Characteristics of Plastic Particles	Particle size	Details	References
Inflammation	Polystyrene particles	202 and 535 nm	* Expression of IL-8 is increased	Deng et al., 2017; Forte et al., 2016; Fuchs et al., 2016; Prietl et al., 2014; Nich and Goodman, 2014; Brown et al., 2011; Green et al., 1998; Devane et al., 1995a,b
	Unaltered/Carboxylated polystyrene nanoparticles	20, 44, 500, and 1000 nm	* Inflammation was induced in human A549 lung cells * Expression of IL-6 and IL-8 is increased	
	Carboxylated and amino-modified polystyrene particles	120 nm	* Multiple human cancers have increased inflammation * Scavenger receptor expression is altered	
	Unaltered polyethylene particles	0–3 µm, 10 µm	* The production of IL-10 was enhanced in M2 cells * TGF (31 (ML) levels have increased, as does energy metabolism (M2)	
	Polyethylene particles from plastic prosthetic implants	0.2 and 10 µm	* Increased IL-6, IL-113, and TNFa production in murine macrophages * TNFct, IL-1, and RANKL expression were all increased	
	Polystyrene MPs particles	5 and 20 µm	* Periprosthetic bone resorption occurred as a result * Induced inflammatory reaction around the implant * The liver is inflamed as a result of the inflammation * Neurotransmission has been harmed as a result of the induction	
Oxidative stress and apoptosis	Amine-modified polystyrene nanoparticles	60 nm	* Mucin has strong interaction and aggregation * Apoptosis was induced in all intestinal epithelial cells	Mahadevan and Valiyaveettil, 2021; Inkielewicz-Stepniak et al., 2018; Liu et al., 2018; Chiu et al., 2015; Ruenraroengsak and Tetley, 2015; Paget et al., 2015; Thubagere and Reinhard, 2010; Xia et al., 2008
	Cationic polystyrene nanoparticles	60 nm	* ROS production and ER stress are both induced * Autophagic cell death in mice macrophages and lung epithelial cells has been induced	
	Unaltered or functionalized polystyrene polyvinyl chloride (PVC) and poly (methyl methacrylate) (PMMA)	20, 40, 50, and 100 nm 120 nm, 140 nm	* Apoptosis was induced in a variety of human cell types * Reduced cell viability due to a decrease in ATP and an increase in ROS levels	
Metabolic homeostasis	Pristine and fluorescent polystyrene MPs	5 µm	* Amino-addition and bile-addition metabolism changes * Induced dysbiosis of the gut microbiota and intestinal barrier failure * Ionic homeostasis and altered ion channel function	Luo et al., 2019a; Jin et al., 2019; McCarthy et al., 2011
	Anionic carboxylated polystyrene nanoparticles	20 nm	* Basolateral K^+ channels that have been activated * Cl^- and HCO_3^- ion outflow is induced	
	Polystyrene nanoparticles	30 nm	* The distribution of cytokinesis-associated proteins and blocked vesicle transit	Stock et al., 2019; Luo et al., 2019a,b; Wang et al., 2020; Deng et al., 2017; Xia et al., 2016; Mahler et al., 2012
	Cationic polystyrene nanoparticles	50 and 200 nm	* Intestinal iron transit and cellular uptake have been disrupted * Hepatic ATP levels are reduced * Deficiency in energy metabolism	
	Pristine polystyrene microparticles	5 and 20 µm	* The metabolic condition is associated with dysbiosis of the gut microbiota and a breakdown of the gut barrier	
	MPs	0.5 and 5 µm	* Increased the chances of metabolic disorders in children	

With this table, the research paper is concluded and achieves the objectives of spreading awareness, examining the content, identifying the need for mitigation, and advancing the knowledge and understanding of how microplastics work. Based on this research paper, various regulatory frameworks, policies, and legislative measures can be formed to improve the world, the ocean, and our health systems.

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